Renewable and Sustainable Energy Reviews 40 (2014) 505–514

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Enhancing the maximum power point tracking techniques for photovoltaic systems

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ARTICLE INFO

Article history:
Received 4 March 2014
Received in revised form
21 July 2014
Accepted 30 July 2014

Keywords:
Renewable energy
Control system
Photovoltaic system
Maximum power point
Genetic algorithm

ABSTRACT

The development of maximum power point tracking (MPPT) is continuing in order to increase the energy transfer efficiency of the solar photovoltaic system. This paper provides a review of the conventional maximum power point tracking techniques that is enhanced by the presentation of a new technique. The new method is based on a genetic neural algorithm in order to predict the closest point to the maximum power point (MPP), which will be the kickoff point of the search process. Not only does the new technique start the search process from the nearest point to the MPP, but also the developed search algorithm is very fast. Consequently, the time taken to reach the MPP is reduced. In order to determine the new MPPT performance, a complete photovoltaic generator system is modeled and simulated using the MATLAB/SIMULINK package. Simulation results show that the new technique reaches the MPP in less than 100 sample times compared to tens of thousands of samples for conventional methods. Furthermore, the new technique reaches directly the target MPP with small deviation from the intended values. Consequently, the new technique has a significant improvement in energy extraction efficiency from the photovoltaic array to the load, in addition to higher tracking speed and system stability compared to the conventional ones.

Contents

1. Introduction

Photovoltaic generation systems have two major problems. The conversion efficiency of electric power generation is low (9–17%) especially under low irradiation conditions, and the amount of

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http://dx.doi.org/10.1016/j.rser.2014.07.202
1364-0321/

electric power generated by the solar arrays changes continuously according to the weather conditions and daytime [1]. Moreover, the solar cell *I–V* characteristic is nonlinear and varies according to the irradiation (*G*) and the temperature (*T*). In general, there is a unique point on the current–voltage *I–V* or power-voltage *P–V* curve of a photovoltaic array where the output power from the array has a maximum value. To extract the maximum power from the array, it must have been operated continuously at this maximum power point (MPP). Because of the nature of the photovoltaic generator, the maximum output power changes with the incident solar radiation and weather conditions especially the temperature. The location of the MPP on the *I–V* curve of the array could not be easily known. Therefore, it must be determined either through calculation models or by search algorithms [2]. Therefore, appropriate maximum power point tracking (MPPT) technique is needed to maintain the operating point of the PV array at the MPP under any operating conditions. In addition, the fast tracking response is necessary for continuous extraction of the maximum power from the array even at high-speed changes in the incident solar radiation. The concept applied here is to conserve every generated watt from the expensive and relatively low efficiency solar generator like the photovoltaic array.

This paper provides a review of the conventional maximum power point tracking techniques that is enhanced by the presentation of a new technique. The new MPPT method concentrates on minimizing the amount of time taken to reach the MPP and hence the system operating point is kept mostly at the MPP. Consequently, the extracted energy from the source is maximized. The genetic algorithm (GA) is used for searching the training database to get the optimum value of the maximum power point. Then, this point will be the starting point of the search process. This guarantees that the search process starts from the closest point to the MPP. On the other hand, the developed search technique in this method reaches the target point in the shortest time. The whole system is modeled and simulated using the MATLAB/SIMULINK package. The rest of the paper is organized such that, Section 2 describes the materials and methods, Section 3 introduces the simulation results and Section 4 concludes the work.

2. Materials and methods

There are intensive and continuous research efforts on the maximum power point tracking of the photovoltaic power generators to improve their performance parameters. The target is to improve their efficiency, and maximize their extracted power. In this section, the maximum power point tracking techniques are reviewed in order to show their main features and drawbacks.

The incremental conductance (INC) and perturb and observe (P&O), are the most efficient MPPT methods [3,4]. Furthermore, the MPPT technique, which is based on the PI controller or the artificial intelligence controller, has an improvement in efficiency [5,6].

Most commonly used techniques of MPPT are: Perturb and observe (P&O), Hill-climbing, Constant voltage and Current, Incremental conductance, Parasitic capacitance, and Swarm chasing along with some DSP based methods [7,8].

The P&O method is simple, but its steady state error is large. Moreover, it oscillates at steady state operation in the vicinity of maximum power point [7–12]. The parasitic capacitance method gets stuck at local maxima or minima [13]. The modified P&O technique improves convergence in rapidly changing weather pattern, but does not enhance the efficiency [14,15]. Hill climbing method is widely applied in the MPPT controllers due to its simplicity and easy implementation. Nevertheless, steady-state oscillations always appear due to the perturbation. Thus, its power loss may be increased [9,10]. Incremental conductance has proved to be better in terms of efficiency, but one major problem is that power of solar panel is a non-linear function of duty cycle [8,9,11,16–19]. Fractional open-circuit voltage and short-circuit current methods provide a simple and effective way to acquire the maximum power. However, they require periodical disconnection or short-circuit of the PV modules to measure the open-circuit voltage or the short-circuit current for reference resulting in more power loss. In addition, these methods cannot always produce the maximum power available from PV arrays due to the use of predefined PV curves, that often cannot effectively reflect the real-time situation, owing to PV nonlinear characteristics and weather conditions [11,20,21].

On the other side, fuzzy and neural network methods that focus on the nonlinear characteristics of the PV array provide good alternatives for MPPT control. Since the output characteristics of the PV array should be well ascertained to create the MPPT control rules, the versatility of these methods is limited [22,23].

The neural network based controllers can track the maximum power point online; but they have a high cost of implementation owing to complex algorithms that usually need a DSP as their computing platform [11]. In addition, they face a trade-off between settling time and steady state error. Furthermore, their response is very slow [18].

To summarize, Table 1 shows the efficiency of the MPPT algorithms.

It is clear from the table that the efficiencies of the different algorithms are sufficiently high.

Table 2 outlines the main features of the different MPPT techniques [24].

Table 1
MPPT algorithm efficiency.

Ref.	Reported MPPT efficiency			
	P&O	Incremental conductance	Constant voltage	AI techniques
[18]				98% (PSO)
[25]				
[26]				98.7% (ANN—P&O) 99.2% (Fuzzy Logic)
[18]			99%	
[13]				
[13]		98%		
[27]		98.2%		
[28]			95%	
[19]			98.7%	
[12]	98.1%			
[27]				

Table 2
Characteristics of different MPPT techniques.

MPPT techniques	Convergence speed	Complexity	Periodic tuning
Perturb and observe	Varies	Low	No
Incremental conductance	Varies	Medium	No
Fractional open circuit voltage	Medium	Low	Yes
Fractional short circuit current	Medium	Medium	Yes
Fuzzy logic control	Fast	High	Yes
Neural network	Fast	High	Yes

For each algorithm, there exist few drawbacks such as being caught in maxima, high steady state error, and inability to follow the direction of change in perturbation.

The next sections present the development, simulation, and validation of a new developed MPPT technique that preserves the good features and advantages and resolves the drawbacks of the conventional techniques.

2.1. System model description and operation

In this section, the model of a general photovoltaic generator is described in full details. This model is required for the calculation of the system performance and the determination of its performance parameters. As shown in Fig. 1, the model of a photovoltaic system is mainly composed of the PV array of panels, the MPPT Controller, the DC–DC converter and the grid connected inverter. The PV panels are the power source, which supply the system with the DC power. The DC–DC converter boosts the input DC voltage to the desired DC value according to the value of its duty cycle (D). The MPPT controller adjusts the duty cycle D in order to keep the panels operating point, mostly at the MPP. For sake of comparison and getting out the most convenient mode of operation of the MPPT controller, it operates in three modes. Mode I is the MPPT with no control, where there is no control method is integrated with the MPPT. Mode II, the MPPT is based on a genetic algorithm controller. In this mode, if any changes in the ambient temperature and/or the irradiance are sensed, the GA controller searches the training database, and updates the system with the obtained optimum power point parameters. Mode III, the MPPT is based on PI controller. In this mode, if any changes in the ambient temperature and/or the irradiance are sensed, the PI controller updates the current according to the reference current I_{ref}. The three modes of operation are schematically shown in the system block diagram in Fig. 1.

2.2. Photovoltaic array

Here we assume that the photovoltaic array is composed of one panel without loss of generality of the system. A PV module is formed by connecting solar cells in series and parallel, according to the required output current and voltage. A typical model for a solar cell is shown in Fig. 2 [29].

The standard model equations are given by

$$I = I_{pv} - I_o(e^{\frac{q(V+IR_s)}{AKT}} - 1) - \frac{(V+IR_s)}{R_{sh}} \tag{1}$$

$$I_o = I_{oref}(T/T_o)^3[e^{qEg\frac{(1/T_o)-(1/T)}{AK}}] \tag{2}$$

$$I_{pv} = \{I_{sc} + K_i(T-25)\}G \tag{3}$$

$$T = 3.12 + 0.25(G/G_{ref}) + (0.899T_a) - (1.3W_s) + 273 \tag{4}$$

Where I is the cell output current (A), V is the cell output voltage (V), I_{pv} is the photo current (A), I_o is the cell reverse saturation current (A), I_{oref} is the reference cell reverse saturation current at T_o (A), I_{sh} is the shunt current (A), R_{sh} is the parallel resistance (Ω), R_s is the series resistance (Ω) K is the Boltzmann constant = 1.38 × 10^{-23}(J/K), T is the solar cell temperature (°C), $q$is the charge of electron = 1.6 × 10^{-19} C, K_i: is the short circuit current temperature coefficient at I_{sc}, I_{sc} is the short circuit current at 25 °C (A), G is the irradiance intensity (W/m^2), G is the Irradiance intensity (W/m^2), G_{ref} is the reference irradiance intensity 1000 (W/m^2), T_a is the ambient temperature (°C) and W_s is the local wind speed (m/s).

The characteristic equation of a solar module, depends on the number of cells in parallel (N_P), and the number of cells in series (N_s). The current variation is less dependent on the shunt resistance, and is more dependent on the series resistance [29].

$$I = N_P I_{pv} - N_P I_o(e^{q\frac{((N_s/N_P)+I(R_s/N_P))}{AKT}} - 1) - \frac{V(N_P/N_s) + IR_s}{R_{sh}} \tag{5}$$

In the presented system, the PV model is designed based on the data-sheet parameters of the BP485J module [30]. In this model, I_{pv} is an input; which is suitable for series connections. The module data-sheet parameters are shown in Table 3.

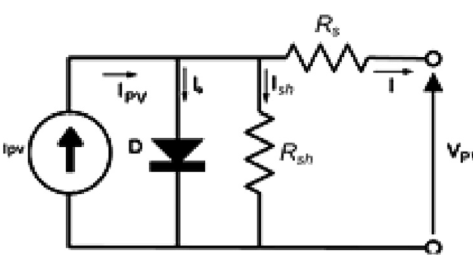

Fig. 2. Equivalent circuit model of PV Cell.

Table 3
PV module parameters.

Parameter	Variable	Value
Maximum power	P_m	84.816 W
Voltage at maximum power	V_m	17.1 V
Current at maximum power	I_m	4.96 A
Open-circuit voltage	V_{oc}	22.2 V
Short-circuit current	I_{sc}	5.45 A

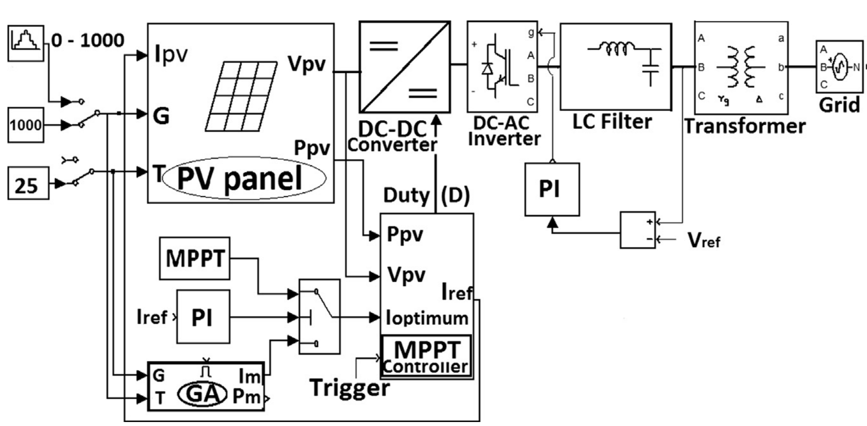

Fig. 1. Grid connected photovoltaic system model block diagram.

2.3. The new MPPT technique

After modeling the photovoltaic array, the new MPPT technique is introduced in this section. The new maximum power point search method makes full use of the fact that there is only one maximum power point in the whole search range from zero voltage to the open circuit voltage V_{oc}. To the left of this point the slope dP/dV is positive while it is negative on the right side. This method does not scan every point like the traditional methods [30]. But every time the search region is divided into two parts. Based on the observation results of the slope dP/dV, one part is selected to be the new search region and the other part is discarded. For example, when taking (V_{oc} /2) as the starting region from [0 to V_{oc} /2] or on the right region from [V_{oc} /2 to V_{oc}], according to the observation of(dP/dV). If (dP/dV) is greater than zero, all points of the left region will be discarded, and the new search region is divided into two parts, also the new starting point will be updated to (3V_{oc} /4). Again, the MPP is located either on the left region from [V_{oc} /2 to 3V_{oc} /4] or in the right region from [3V_{oc} /4 to V_{oc}], and so on. Consequently, for every observation time, a half of the search region is discarded and consequently, the search time is appreciably reduced compared to the conventional search methods.

Fig. 3 shows the flow chart of the new MPPT method. In initializing section, the starting points ($\boldsymbol{V_{start}}$) and ($\boldsymbol{P_{start}}$) are initialized, also the ending points ($\boldsymbol{P_{end}}$) and($\boldsymbol{V_{end}}$) are initialized**,** then the operating point ($\boldsymbol{P_{current}}$) is moving according to the prescribed logic until it reaches the target point which is the peak power point.

2.4. Optimization of the new MPPT method using the genetic neural network

In addition to speeding up the maximum power point search, it is also required to start the search from a point as close as to the target maximum power point.

This will lead to a further shortening of the search time to a minimum leading to a rapid following of fast changes in the maximum power of the photovoltaic array. In fact, the ideal tracking system must always coincide with the maximum power point curve under any operating conditions. In this way, the maximum transfer of power from the photovoltaic array is realized and consequently the efficiency of the PV system is maximized. The genetic algorithm is used for that job, where a feed forward neural network is trained by using a set of temperature and solar radiation records to find the maximum power point value. Then the system parameters are updated by the obtained maximum power value. This training data is generated using the PV model, and it is supposed to be replaced by the actual measurements of the PV module at implementation time. The proposed ANN is shown in Fig. 4. It has three layers, which are the input layer, the hidden layer, and the output layer. The input layer has four neurons, which are the solar irradiation G (W/m^2), the temperature T (°C), the temperature coefficient of $I_{sc}(\alpha_i)$ and the temperature coefficient of $V_{oc}(\alpha_v)$. The output layer is the predicted optimum current $I_{optimum}$(A). The hidden layer is the processor of the genetic algorithm. It employs the cognitive function to drive the GA tool of MATLAB/SIMULINK. It is developed based on the following model equations [31]:

$$I_{SC} = I_{SCS}(G/G_s) + \alpha_i(T - T_S) \tag{6}$$

$$V_{OC} = V_{OCS} + \alpha_v(T - T_S) - (I_{SC} - I_{SCs}) \tag{7}$$

Where I_{SCS} is the short-circuit current of the PV module at reference solar radiation (A), V_{OCS} is the open-circuit voltage at the reference temperature (V), α_i is the temperature coefficient of I_{sc} and α_v is the temperature coefficient of V_{OC}.

In order to get the optimum power from the PV system, it is necessary to determine the optimum voltage and optimum current [31].

$$I_{optimum} = K_i I_{sc} \tag{8}$$

$$V_{optimum} = K_v V_{oc} \tag{9}$$

where K_v and K_i are proportional factors with typical values in the ranges of (0.75–0.85) and (0.9–0.92), respectively.

The interface between the MPPT and the genetic neural network is shown in Fig. 5, which shows that the MPPT controller is updated by the optimum value obtained by the GA controller. The genetic algorithm cycles and stages are shown In Fig. 6. It shows that initial generation is created and encoded in the initialization section. Then, the generation is evaluated by using the fitness

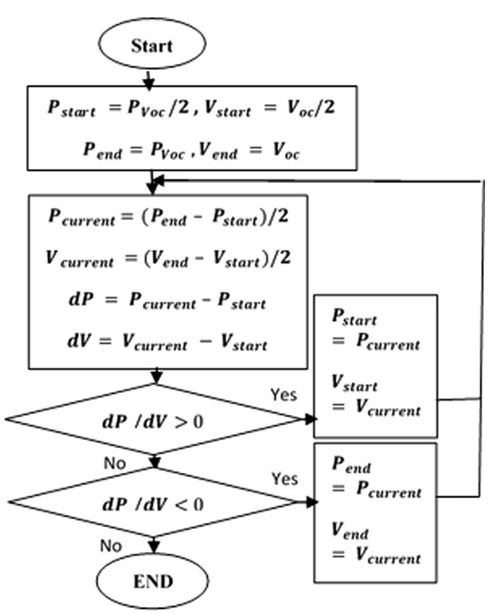

Fig. 3. The flowchart of the new MPPT method.

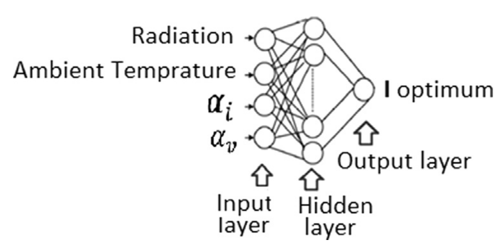

Fig. 4. The ANN Layers.

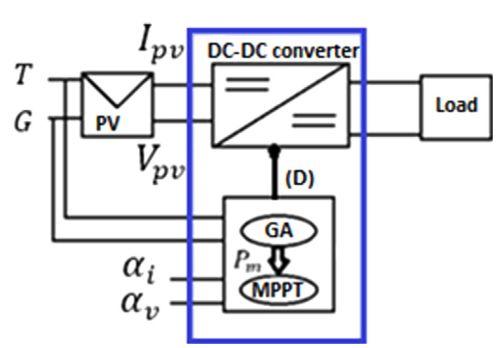

Fig. 5. GA interfaces with MPPT.

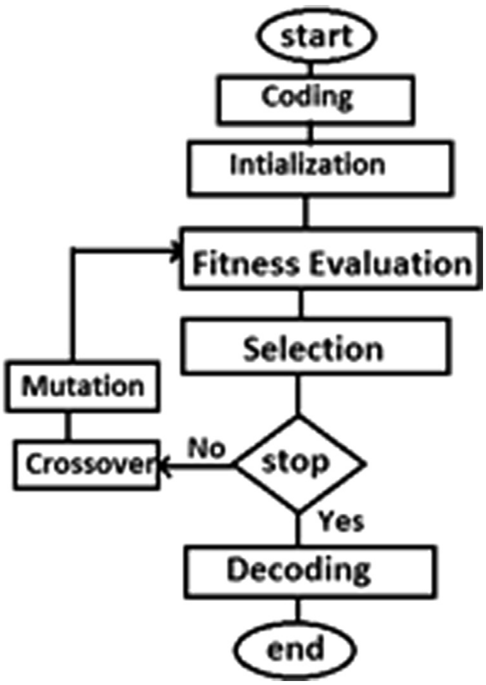

Fig. 6. Chart of the GA reproduction cycle and stages.

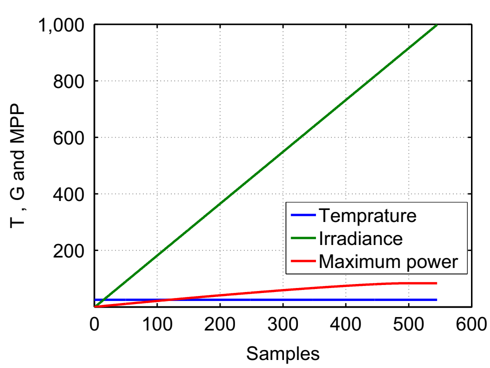

Fig. 7. MPP location changed with irradiance change.

Table 4
Samples of the training data, which is obtained by the PV model.

T	G	V_m	I_m	V_{oc}	I_{sc}	P_m
25	250	20.35	1.240	26.262	1.3634	25.2525
25	500	19.29	2.480	24.900	2.7259	47.8696
25	1000	17.18	4.960	22.175	5.4509	85.2462
10	250	21.31	1.199	27.507	1.3184	25.5756
10	500	20.26	2.439	26.145	2.6809	49.4323
10	1000	18.15	4.919	23.420	5.4059	89.2900
50	250	18.74	1.308	24.187	1.4384	24.5358
50	500	17.68	2.548	22.825	2.8009	45.0869
50	1000	15.57	5.028	20.100	5.5259	78.3335

function, and the fittest items are selected based on the evaluation results. Mutation and crossover are used in order to create new generations. The process is repeated until one of the termination conditions is realized. Termination conditions are: the number of generations, time limit, fitness limit, stall generation, stall time limit, function tolerance and nonlinear constraint tolerance.

Fig. 7 shows the MPP values as a function of the solar radiation and temperature. For every change in temperature and/or irradiance, there will be a record for the optimum voltage (V_m),

Table 5
A comparison between a representative calculated values and the obtained values by the GA model.

G	Obtained data			Calculated data		
	V_m	I_m	P_m	V_m	I_m	P_m
250	20.35	1.240	25.234	20.38	1.242	25.31
500	19.29	2.480	47.839	19.33	2.482	47.97
1000	17.18	4.960	85.24	17.22	4.962	85.44

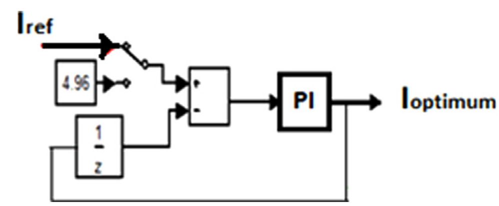

Fig. 8. PI controller model.

optimum current (I_m), and optimum power (P_m). Regarding the weather in Egypt, temperature ranges from 10 °C to 50 °C and irradiance ranges from 0 to 1000 (W/m^2). Consequently, there will be 8000 records of solar radiation and temperature. This data is used in order to train, validate, and test the proposed network.

The developed GA processor, searches the training database to get the optimum power point value, which is the nearest point to the MPP. So, the search time is minimized, and in turn, the search is accelerated. A sample of the training data is shown in Table 4.

In order to validate the developed GA model, the obtained data is compared to the calculated data in Table 5.

In order to show the merits of the proposed optimization using genetic algorithm, A conventional PI controller is added to the system to compare the GA with it. Fig. 8 shows that, the PI controller drives the system current to follow the reference current.

3. Simulation and results

After building the SIMULINK model of the new MPPT controller, it is simulated to work out its main performance parameters and compare it to the conventional MPPT controllers. Therefore, three modes of operation are planned and investigated which are the MPPT with no control, the PI controller based MPPT and the GA controller based MPPT. In addition, there are three test cases: test case I, where the temperature and irradiance are fixed, test case II, where the temperature and/or irradiance are changed, test case III, where the new MPPT technique is used. In each test case, the system will run under every mode of operation and the results are compared.

3.1. Test case I, fixed temperature and irradiance

In this case, a unit step change in the array voltage, current and power are the inputs to the controller. Figs. 9–11 show the current, the voltage, and the power respectively as a function of time which is represented by the number of samples. They show that the GA controller based MPPT takes the shortest time to reach the MPP. While the PI controller based MPPT takes more time to reach the MPP. But the MPPT with no control, is the last one to reach the MPP.

Fig. 12 shows the details of the first 10 samples of Fig. 11 to resolve the rapid change in power of the GA controller. It is clear from this figure that when using the GA controller based MPPT

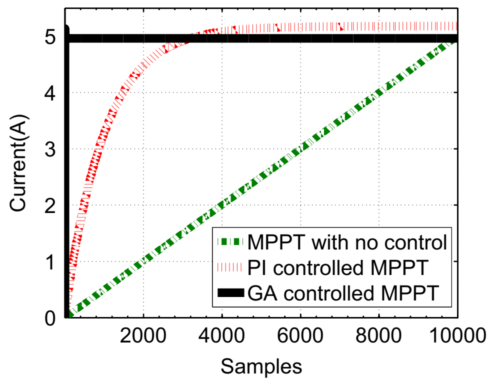

Fig. 9. The PV current of GA controller based, PI controller based and MPPT with no control.

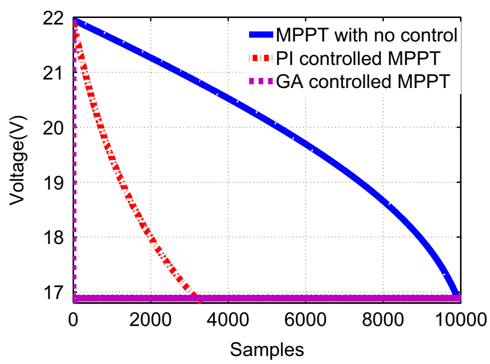

Fig. 10. The PV Voltage of GA controller based, PI controller based and MPPT with no control.

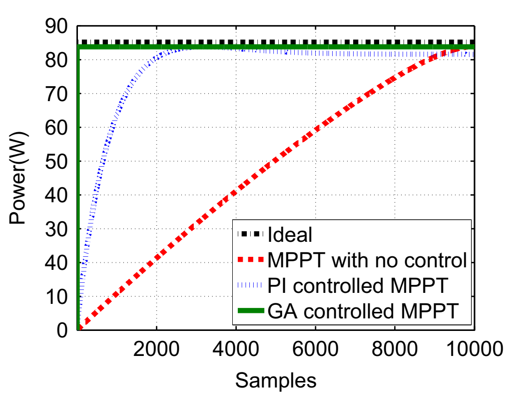

Fig. 11. The PV power of GA controller based, PI controller based and MPPT with no control.

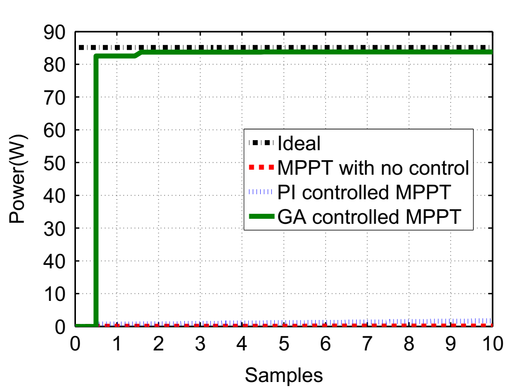

Fig. 12. The PV power of GA controller based, PI controller based and MPPT with no control through the first 10 samples.

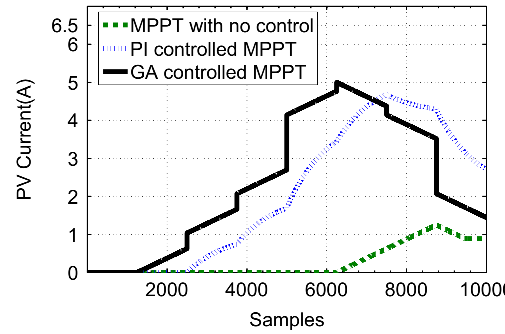

Fig. 13. PV current changes due to irradiance change of MPPT with no control, GA controller based MPPT and PI controller based MPPT.

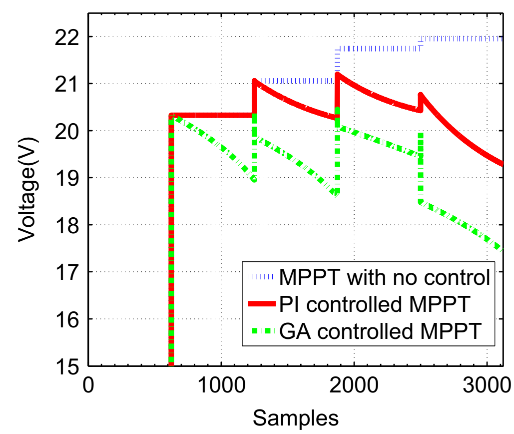

Fig. 14. PV voltage changes due to irradiance change of MPPT with no control, GA controller based MPPT and PI controller based MPPT.

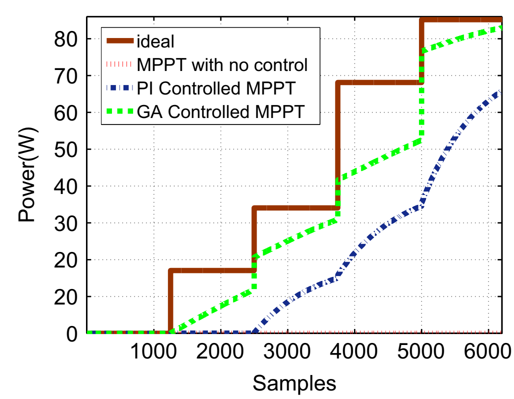

Fig. 15. PV power changes due to irradiance change of MPPT with no control, GA controller based MPPT and PI controller based MPPT.

method, the MPP is reached within the first 10 samples while the power is still zero at its initial state in the other methods.

3.2. *Test case II, varying temperature, and/or irradiance with time*

To approach the practical operating conditions of the system in this test, the irradiance is assumed to vary as a stair case function with step values of 0, 200, 400, 600, 800 and 1000 W/m^2. The controller will receive a trigger signal, which represents the sensed change in irradiance. Furthermore, there is another input to the controller, which is a mode signal that identifies which mode of operation to be run.

Fig. 13–15, representing the current, voltage and power dynamic curves respectively, show that the MPPT with no control,

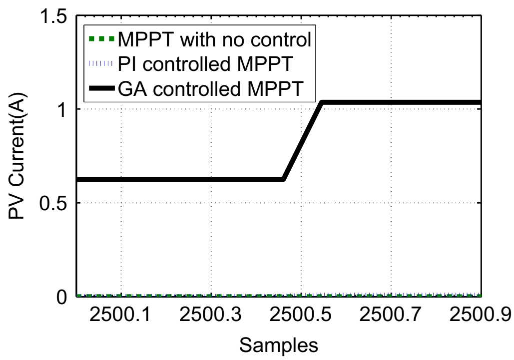

Fig. 16. PV power changes due to irradiance change in a period of one sample.

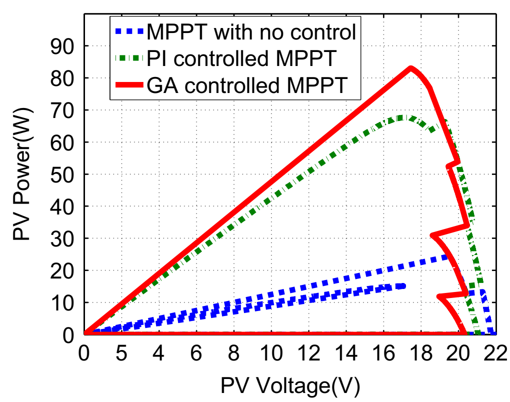

Fig. 17. *P–V* curve changes due to irradiance change of MPPT with no control, GA controller based MPPT and PI controller based MPPT.

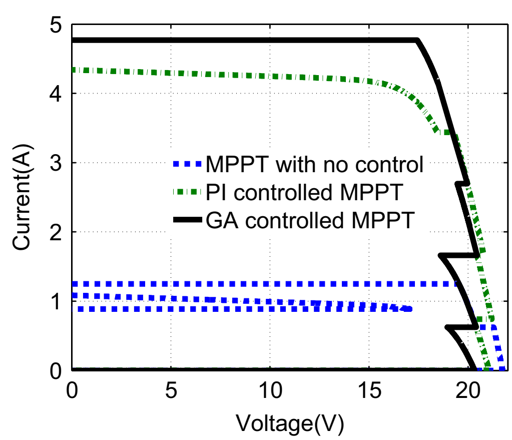

Fig. 18. *I–V* curve changes due to irradiance change of MPPT with no control, GA controller based MPPT and PI controller based MPPT.

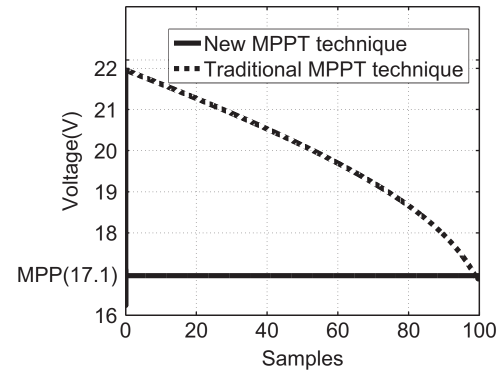

Fig. 19. The voltage of the new MPPT technique compared to the traditional MPPT techniques.

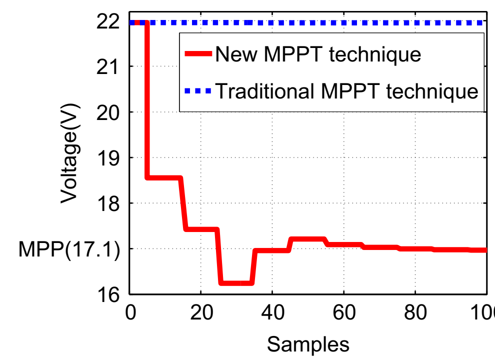

Fig. 20. The first 100 samples of the voltage of the new MPPT technique versus the traditional MPPT techniques.

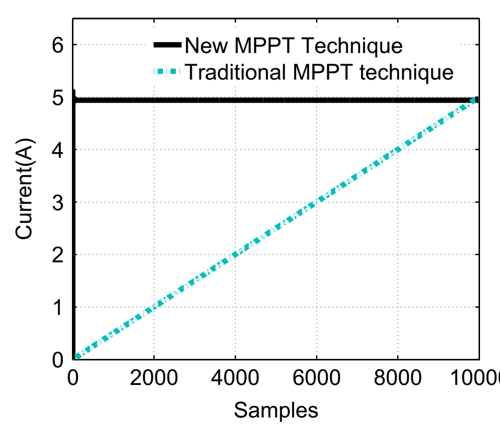

Fig. 21. Current curve of the new MPPT technique versus the traditional MPPT techniques.

has the slowest tracking response to the irradiance changes, while the PI controller based MPPT has the intermediate speed response. But the GA controller based one, has the fastest tracking response.

Because the tracking response of the GA based controller is very fast, and almost coincides on the target power, we resolved only one sample time at the sample number 2500, where a star occurs as shown in Fig. 16. The figure shows that, in the PI controller based MPPT, and the MPPT with no control, there is no change in current while it raises up gradually in the GA controller based MPPT.

The *P–V* and *I–V* curves are affected by the irradiance change as depicted in Figs. 17 and 18. These figures show that, the MPPT with no control is the slowest response to the irradiance change and so it is the lowest output power curve. The PI controller based MPPT, is slightly faster in response and higher in power. While the GA controller based MPPT is the fastest in response, and works mostly at the maximum power.

3.3. Test case III, the new MPPT test

The new MPPT technique is compared graphically to the traditional techniques in Figs. 19, 21, 23, and 25 to represent the voltage, current, power and efficiency curves, respectively. These figures show that the new MPPT technique reaches the MPP in less than 100 samples or iterations, while the traditional methods reaches the MPP after tens of thousands of samples. Figs. 20, 22, 24 and 26 show the hidden details of the first 100 samples. It is clear that the new technique reaches the target value in less than 100

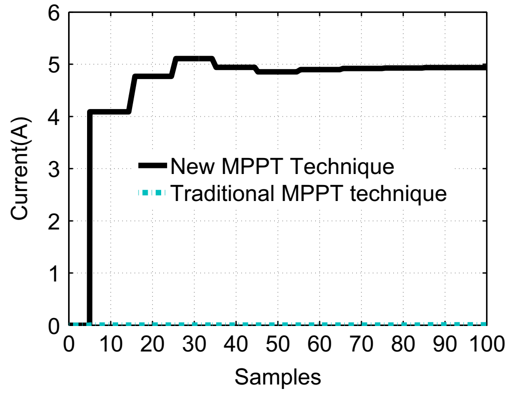

Fig. 22. The first 100 samples of the current curve of the new MPPT technique compared to the traditional MPPT techniques.

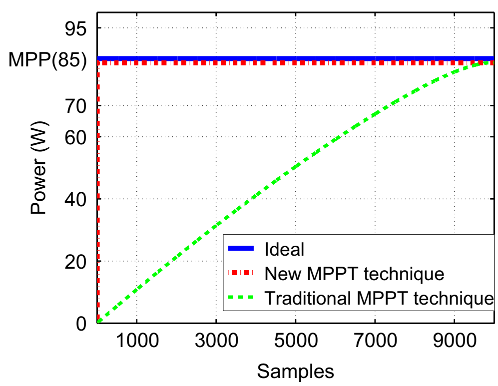

Fig. 23. Power curve of the new MPPT technique compared to the traditional MPPT technique.

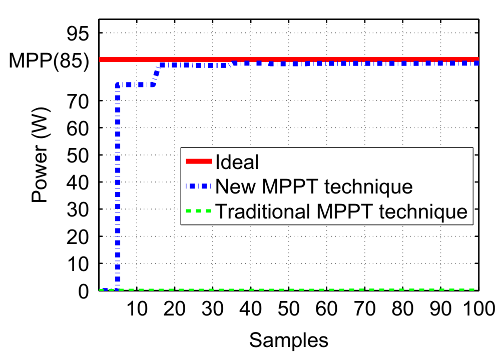

Fig. 24. The first 100 samples of the power curve of the new MPPT technique versus the traditional MPPT techniques.

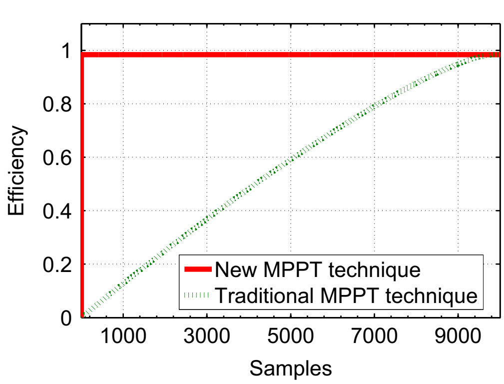

Fig. 25. Efficiency of the new MPPT technique versus the traditional techniques.

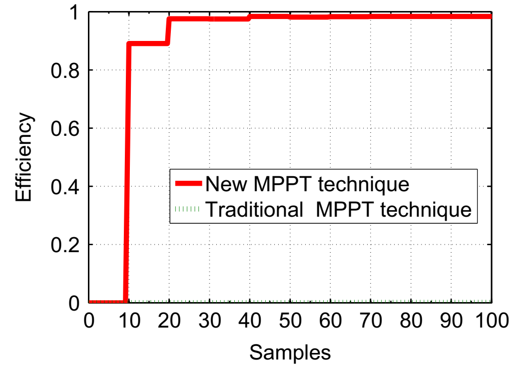

Fig. 26. The first 100 samples of efficiency of the new MPPT technique compared to the traditional MPPT techniques.

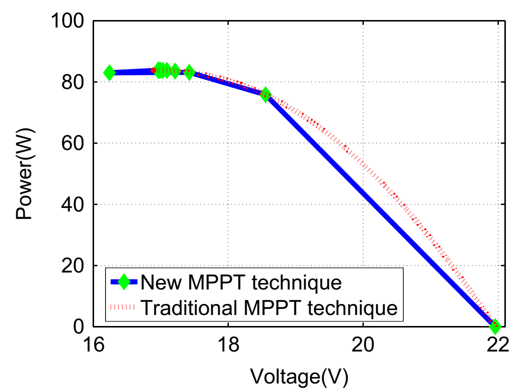

Fig. 27. The *P–V* curve of the new MPPT technique compared to the traditional technique.

samples while the traditional methods need tens of thousands of samples to arrive the same value.

A comparison between the *P–V* curve of the new MPPT technique and the traditional MPPT techniques is depicted in Fig. 27. It is observed that, in the new technique, the MPP is reached in less than 100 samples while the traditional MPPT techniques arrived the MPP after tens of thousands of samples.

3.4. Validation

The presented system is modeled based on standard model equations [29]. The theoretical output voltage, current and power of the model are calculated for different irradiance and compared to the obtained values by using the simulation model. This is done for every mode of operation. Table 6 shows that, the deviation from the calculated values is very limited, especially in the new MPPT technique.

The simulation model is developed based on the Data-sheet parameters of the BP485J module [30]. For more validation, the module parameter values are compared to the obtained values in Table 7.

To validate the new developed method, its efficiency is compared to the previously developed methods using conventional algorithms as P&O, INC,. etc. as shown in Table 8. From the table, it is seen that the efficiency of the developed method is basically better than the conventional ones.

4. Conclusion

This paper collects the features and drawbacks of the MPPT techniques based on a deep review to the most recent publications

Table 6
A comparison between a representative calculated values and the model obtained results of PV array current (I_{pv}), PV array voltage (V_{pv}), PV array power (P_{pv}) and the deviation in power (δP).

G W/m^2	Obtained data MPPT with no control			PV panel calculated data			δP
	I_{pv}	V_{pv}	P_{pv}	I_{pv}	V_{pv}	P_{pv}	
200	0.89	16.83	15.08	0.886	17.0	15.1	0.03
400	1.91	17.35	33.13	1.9	17.4	33.1	0.00
800	3.96	17.08	67.64	3.95	17.1	67.6	0.00
G W/m^2	Obtained data MPPT based on GA control			PV panel calculated data			
	I_{pv}	V_{pv}	P_{pv}	I_{pv}	V_{pv}	P_{pv}	δP
200	0.89	16.83	15.08	0.886	17.0	15.1	0.03
400	1.91	17.35	33.13	1.9	17.4	33.1	0.00
800	3.96	17.08	67.64	3.95	17.1	67.6	0.00
G W/m^2	Obtained data New MPPT technique			PV panel calculated data			
	I_{pv}	V_{pv}	P_{pv}	I_{pv}	V_{pv}	P_{pv}	δP
200	0.88	17.06	15.1	0.886	17.0	15.1	0.00
400	1.90	17.43	33.13	1.9	17.4	33.1	0.00
800	3.94	17.13	67.64	3.95	17.1	67.6	0.00

Table 7
A comparison between the module datasheet parameter values and the obtained values. by the GA model.

T	G	PV module parameters			Obtained values		
Simulation model in the mode of MPPT with no control							
25	1000	V_m	I_m	P_m	V_m	I_m	P_m
		17.1 V	4.96 A	84.816 W	16.71	4.95	83.72
Simulation model in the mode of GA controlled MPPT							
25	1000	V_m	I_m	P_m	V_m	I_m	P_m
		17.1 V	4.96 A	84.816 W	17.18	4.960	85.24
Simulation model in the mode of PI controlled MPPT							
25	1000	V_m	I_m	P_m	V_m	I_m	P_m
		17.1 V	4.96 A	84.816 W	16.29	5.1	83.1
Simulation model in the mode of the new MPPT technique							
25	1000	V_m	I_m	P_m	V_m	I_m	P_m
		17.1 V	4.96 A	84.816 W	16.93	4.95	83.8

Table 8
The efficiency of the new method for MPPT compared to previous methods.

	Efficiency	Improvements
Conventional MPPT	97.8 (the mean value) [32]	
The new MPPT method	99%	1.23%

on the topic. Then, it presents a new developed method for tracking the maximum power point, which preserves the good features and avoids the drawbacks of the conventional techniques. The new method is modeled and simulated using the MATLAB / SIMULINK package. The maximum power point tracking process is investigated for general test conditions covering the practical operations of the photovoltaic generator.

Simulation results show that, the new MPPT technique has a significant improvement compared to the traditional methods as it reaches the target MPP in a few number of samples or iterations.

The presented work uses a genetic algorithm to optimize the maximum power point searching process. The results of the performance parameters show that, the new technique gives the most efficient power extraction. The PI controller based MPPT, has a slightly lower efficiency, while the MPPT with no control method possesses the lowest efficiency.

Another important advantage of the new method is that, the MPP can be reached directly with almost very limited swing in the initial phase. Therefore, the system is effectively stable. The consequence of the very fast tracking is that, the average efficiency of the new technique is basically higher than the traditional techniques.

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